

**37. *Plots of Cross Sections and Related Quantities***

# **Atlas of Total Cross Sections**

**COMPETE Soft Physics Working Group proposal  
for the Web version of the 2001 Review of Particle Physics**

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## Introduction

This refreshed version of the “Atlas” of total cross sections is proposed to be included in the Web version of the RPP-2001. This Atlas is based on the 2001 update of the database for total cross section and the ratio of the real-to-imaginary parts of the forward elastic scattering hadronic amplitudes.

New data on total cross sections for  $\gamma\gamma \rightarrow \textit{hadrons}$  from OPAL(CERN-LEP) [1], L3(CERN-LEP) [2] and for  $\pi^-p$  and  $\Sigma^-p$  collisions from SELEX(FNAL) [3] experiments were added. The data from the Fly’s Eye [4] and the Akeno (Agassa)[5] cosmic ray experiments also were added to the evaluated database for the first time.

The decision to include cosmic ray data into the collection of the evaluated database is taken after extensive cross assessments of 37 parameterizations of the forward observables and relevant accelerator data produced during 2000-2001 by the COMPETE collaboration [6].

A special procedure for ranking models, based on several measures of the quality of the fits, was designed in [6]. It allows to single out the safest parametrizations for extrapolations. It turns out that the models which fit best the accelerator data also reproduce the experimental cosmic ray data, without the need of extra phenomenological corrections to the data.

In this Atlas the model of highest rank is proposed to describe the whole 2001 database above  $\sqrt{s} \geq 5$  GeV and including cosmic ray data. It gives the most reliable description of the current experimental database.

***Special suggestion for plots pagination.*** *It will be more suitable if the page with Table 37.2 will be the page with even number.*

## Acknowledgments

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## References

- [1] G. Abbiendi *et al.* [OPAL Collaboration], Eur. Phys. J. **C14** (2000) 199 [hep-ex/9906039].
- [2] M. Acciarri *et al.* [L3 Collaboration], Phys. Lett. B **519** (2001) 33 [arXiv:hep-ex/0102025].
- [3] U. Dersch *et al.* [SELEX Collaboration], Nucl. Phys. **B579** (2000) 277 [hep-ex/9910052].
- [4] R. M. Baltrusaitis *et al.*, Phys. Rev. Lett. **52** (1984) 1380.
- [5] M. Honda *et al.*, Phys. Rev. Lett. **70** (1993) 525.
- [6] J. R. Cudell *et al.* [COMPETE collaboration], on asymptotic behaviour,” hep-ph/0107219.

**Table 37.2: Total hadronic cross section.** Analytic  $S$ -matrix and Regge theory suggest a variety of parameterizations of total cross sections at high energies with different areas of applicability and fits quality.

The special ranking procedure, based on measures of different aspects of the quality of the fits to the current evaluated experimental database allows one to single out the following parameterization of highest rank (see J.R.Cudell et al., hep-ph/0107219)

$$\sigma^{ab} = Z^{ab} + B \log^2(s/s_0) + Y_1^{ab}(s/s_1)^{-\eta_1} - Y_2^{ab}(s/s_1)^{-\eta_2},$$

$$\sigma^{\bar{a}b} = Z^{ab} + B \log^2(s/s_0) + Y_1^{ab}(s/s_1)^{-\eta_1} + Y_2^{ab}(s/s_1)^{-\eta_2}$$

where  $Z^{ab}, B, Y_i^{ab}$  are in mb,  $s, s_1$ , and  $s_0$  are in  $\text{GeV}^2$ . The scales  $s_0, s_1$ , the rate of universal rise of the cross sections  $B$ , and exponents  $\eta_1$ , and  $\eta_2$  are independent of the colliding particles. The scale  $s_1$  is fixed at  $1 \text{ GeV}^2$ . Terms  $Z^{ab} + B \log^2(s/s_0)$  represent the pomerons. The exponents  $\eta_1$ , and  $\eta_2$  represent lower-lying C-even and C-odd exchanges, respectively. Requiring  $\eta_1 = \eta_2$  results in somewhat poorer fits. In addition to total cross section, the measured ratios of the real-to-imaginary parts of the forward scattering amplitudes were included in the fits by using  $s$  to  $u$  crossing symmetry and differential dispersion relations. Global fits were made to the 2001-updated data for  $(\bar{p})pp, \Sigma^-p, \pi^\pm p, K^\pm p, \gamma p$ , and  $\gamma\gamma$ . Exact factorisation hypothesis was used to extend the universal rise of the total hadronic cross sections to the  $\gamma p \rightarrow \text{hadrons}$  and  $\gamma\gamma \rightarrow \text{hadrons}$  collisions. The price of this universality is one extra “asymptotic” parameter  $\delta = \sigma^{\gamma p}/\sigma^{pp}$  for  $s \gg s_0$ . The asymptotic parameters thus obtained were then fixed and used as inputs to a fit to a larger data sample that included cross sections on deuterons ( $d$ ) and neutrons ( $n$ ). All fits were produced to data above  $\sqrt{s_{\min}} = 5 \text{ GeV}$ .

Fits to $\bar{p}(p)p, \Sigma^-p, \pi^\pm p, K^\pm p, \gamma p, \gamma\gamma$			Beam/ Target	Fits to groups				$\frac{\chi^2}{dof}$ by groups
$Z$	$Y_1$	$Y_2$		$Z$	$Y_1$	$Y_2$	$B$	
35.49(47)	42.65(1.35)	33.36(1.04)	$\bar{p}(p)/p$	35.49(47)	42.65(23)	33.36(33)	0.307(10)	1.03
			$\bar{p}(p)/n$	35.83(16)	40.27(1.6)	30.01(96)	0.307(10)	
35.22(1.45)	-206(106)	-271(129)	$\Sigma^-/p$	35.22(1.40)	-206(88)	-271(114)	0.307(10)	0.56
20.88(40)	19.25(1.22)	6.03(19)	$\pi^\pm/p$	20.88(3)	19.25(18)	6.03(9)	0.307(10)	0.96
17.93(36)	7.1(1.5)	13.46(40)	$K^\pm/p$	17.93(3)	7.10(25)	13.46(12)	0.307(10)	0.67
			$K^\pm/n$	17.88(6)	5.12(50)	7.24(28)	0.307(10)	
0.1075(16)	0.0410(81)		$\gamma/p$	0.1075(9)	0.0410(64)		0.307(10)	0.67
2.83(18)E-4	0.32(13)E-3		$\gamma/\gamma$	2.83(17)E-4	0.32(14)E-3		0.307(10)	
$\chi^2/dof = 0.968$ $B = 0.307(10) \text{ mb}$ ,			$\bar{p}(p)/d$	64.45(38)	130(3)	85.6(1.3)	0.534(31)	1.43
$\eta_1 = 0.460(17), \quad \eta_2 = 0.545(7)$			$\pi^\pm/d$	38.66(21)	59.82(1.54)	1.60(41)	0.460(14)	0.73
$\delta = 0.0039(3), \quad \sqrt{s_0} = 5.38(50) \text{ GeV}$			$K^\pm/d$	33.43(20)	23.72(1.45)	28.72(37)	0.449(15)	0.81

The fitted functions are shown in the following figures, along with one-standard-deviation error bands. When the reduced  $\chi^2$  is greater than one, a scale factor has been included to evaluate the parameter values and to draw the error bands. Where appropriate, statistical and systematic errors were combined quadratically in constructing weights for all fits. On the plots only statistical error bars are shown. Vertical arrows indicate lower limits on the  $p_{\text{lab}}$  or  $E_{\text{cm}}$  range used in the fits.

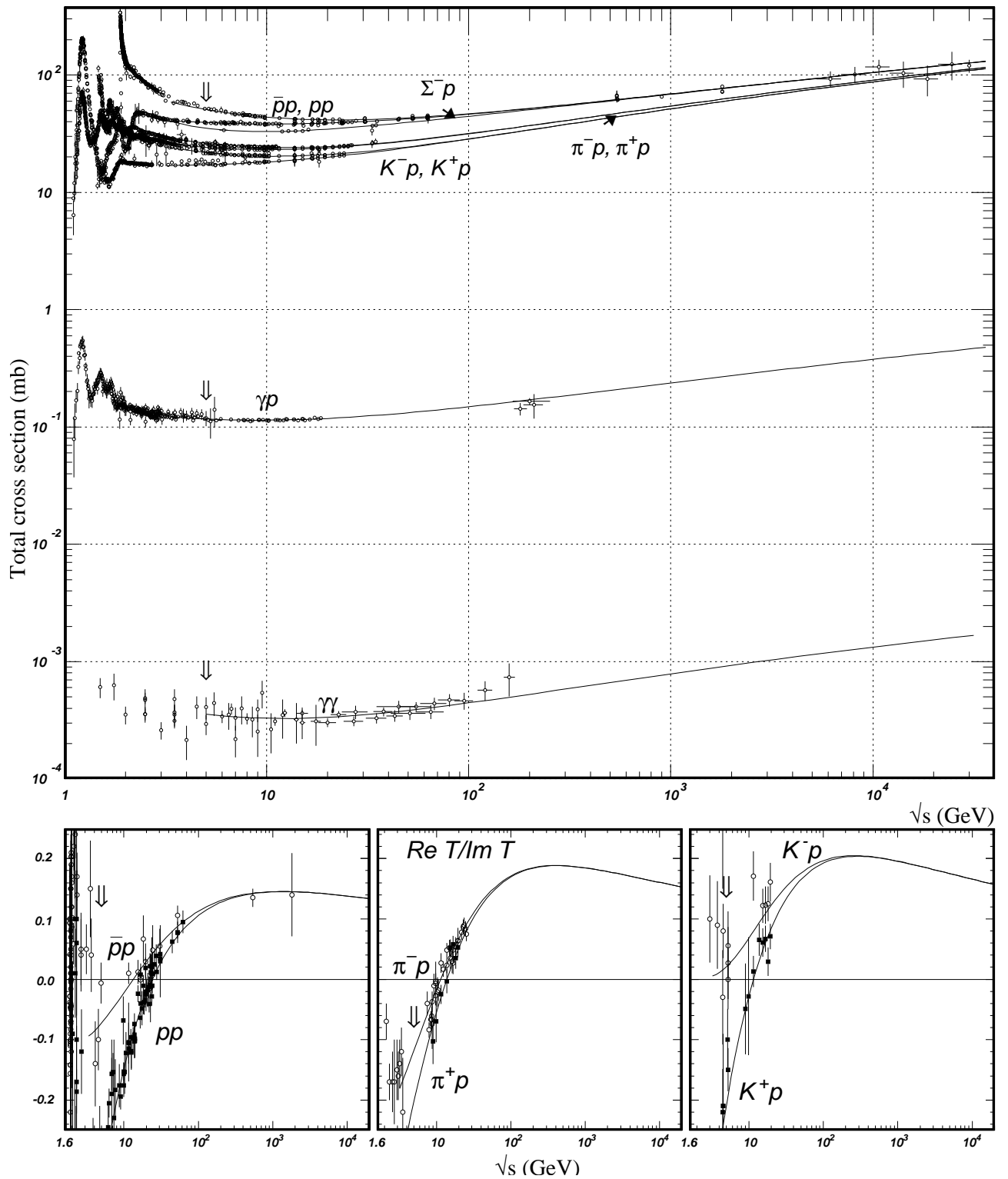
One can find the details of the global fits (all data on proton target and  $\gamma\gamma$  fitted simultaneously) and ranking procedure as well as the exact parametrizations of the total cross sections and corresponding ratios of the real to imaginary parts of the forward scattering amplitudes in the recent paper of COMPETE collaboration cited above. Database used in the fits includes now the recent OPAL and L3 (LEP)  $\gamma\gamma$  data, new highest energy data for  $\pi^-p$  and  $\Sigma^-p$  from SELEX(FNAL) experiment, and cosmic ray data from the Fly’s Eye and AKENO(Agasa) experiments.

The parametrisation of the previous edition can still produces acceptable fits to updated total cross sections database, but only for  $\sqrt{s} > 10 \text{ GeV}$ .

The numerical experimental data were extracted from the PPDS accessible at

<http://wwwppds.ihep.su:8001/ppds.html>

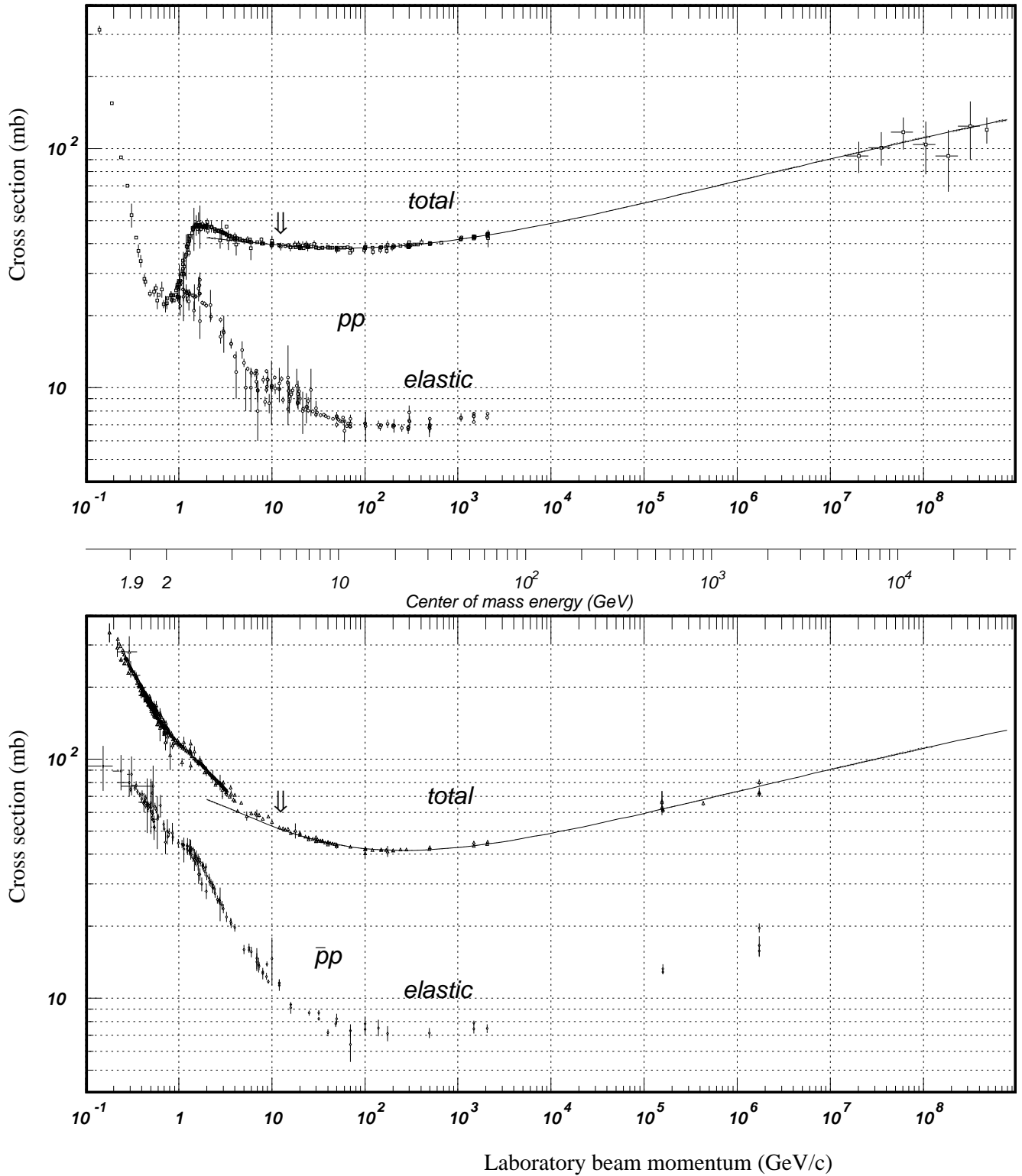
Computer-readable data files are also available at <http://pdg.lbl.gov>. (Courtesy of V.V.Ezhela, Yu.V.Kuyanov, S.B.Lugovsky, E.A.Razuvaev, N.P.Tkachenko, COMPAS group, IHEP, Protvino, Russia, August 2001.)



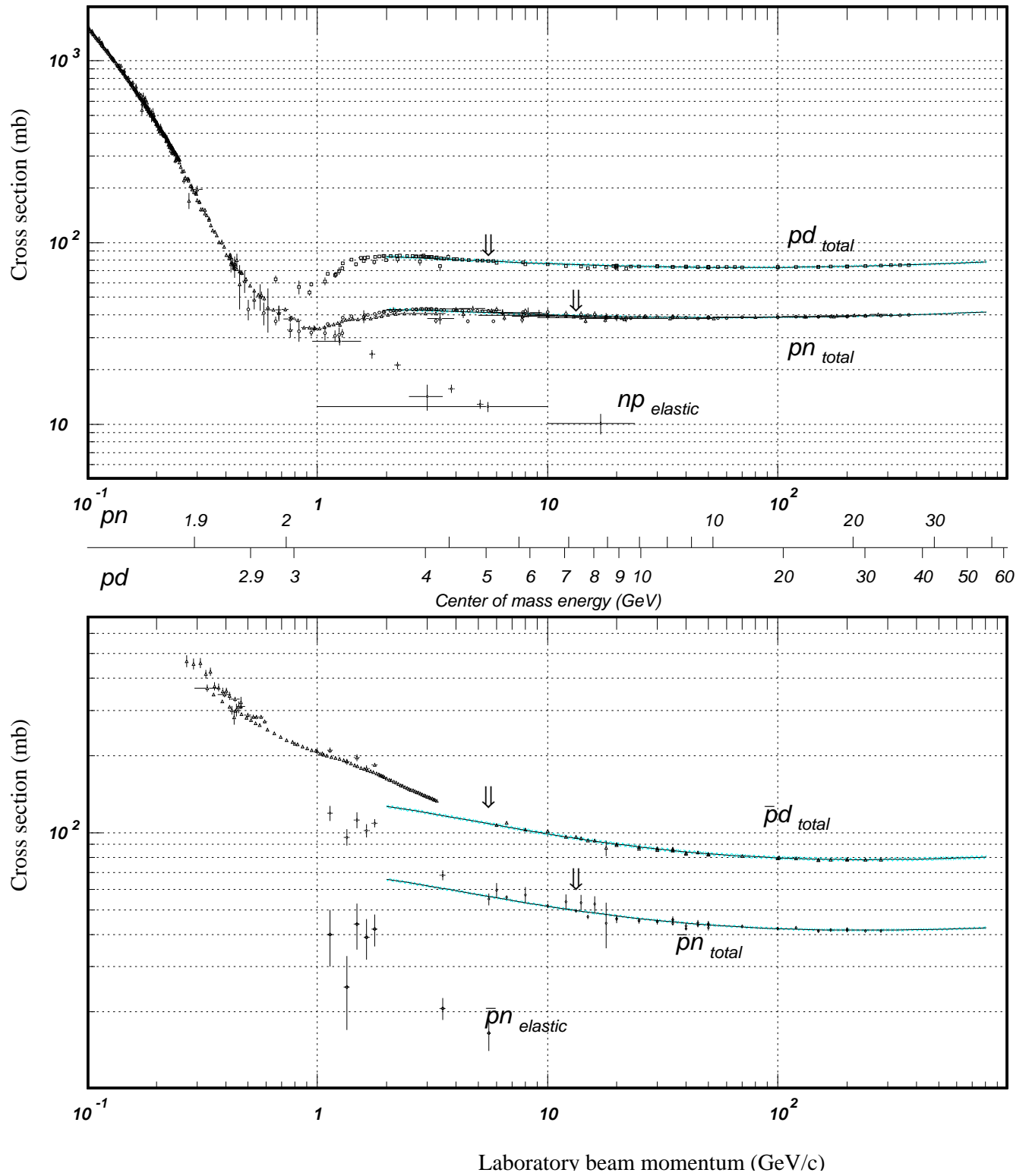
**Figure 37.18:** Summary of hadronic,  $\gamma p$ , and  $\gamma\gamma$  total cross sections, and ratio of the real to imaginary parts of the forward hadronic amplitudes. Corresponding computer-readable data files may be found at

<http://pdg.lbl.gov/xsect/contets.html>

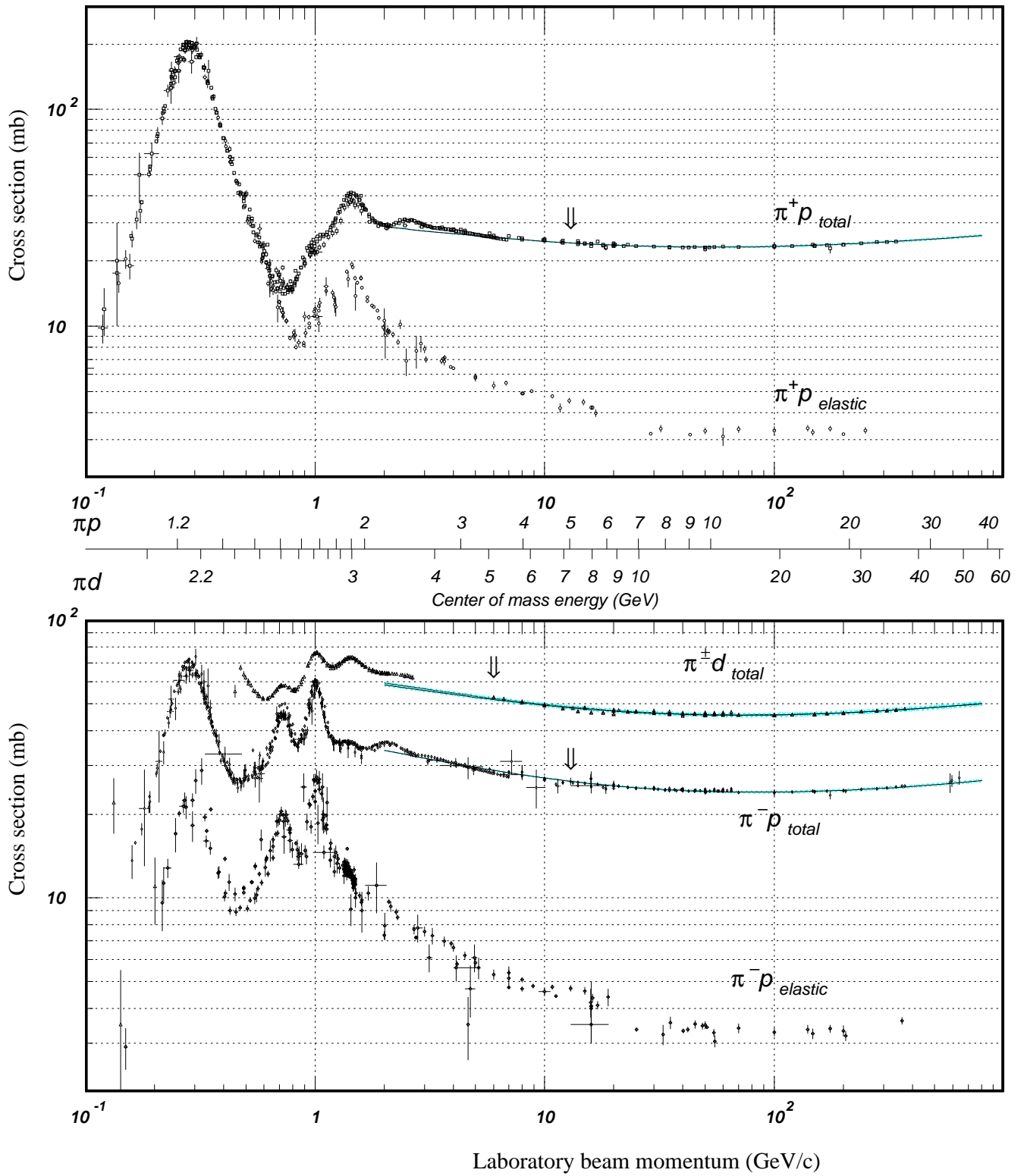
(Courtesy of the COMPAS group, IHEP, Protvino, Russia, July 2001)



**Figure 37.19:** Total and elastic cross sections for  $pp$  and  $\bar{p}p$  collisions as a function of laboratory beam momentum and total center-of-mass energy. The total cross section for  $\Sigma^- p$  collisions is also presented. Corresponding computer-readable data files may be found at <http://pdg.lbl.gov/xsect/contets.html> (Courtesy of the COMPAS group, IHEP, Protvino, Russia, July 2001)

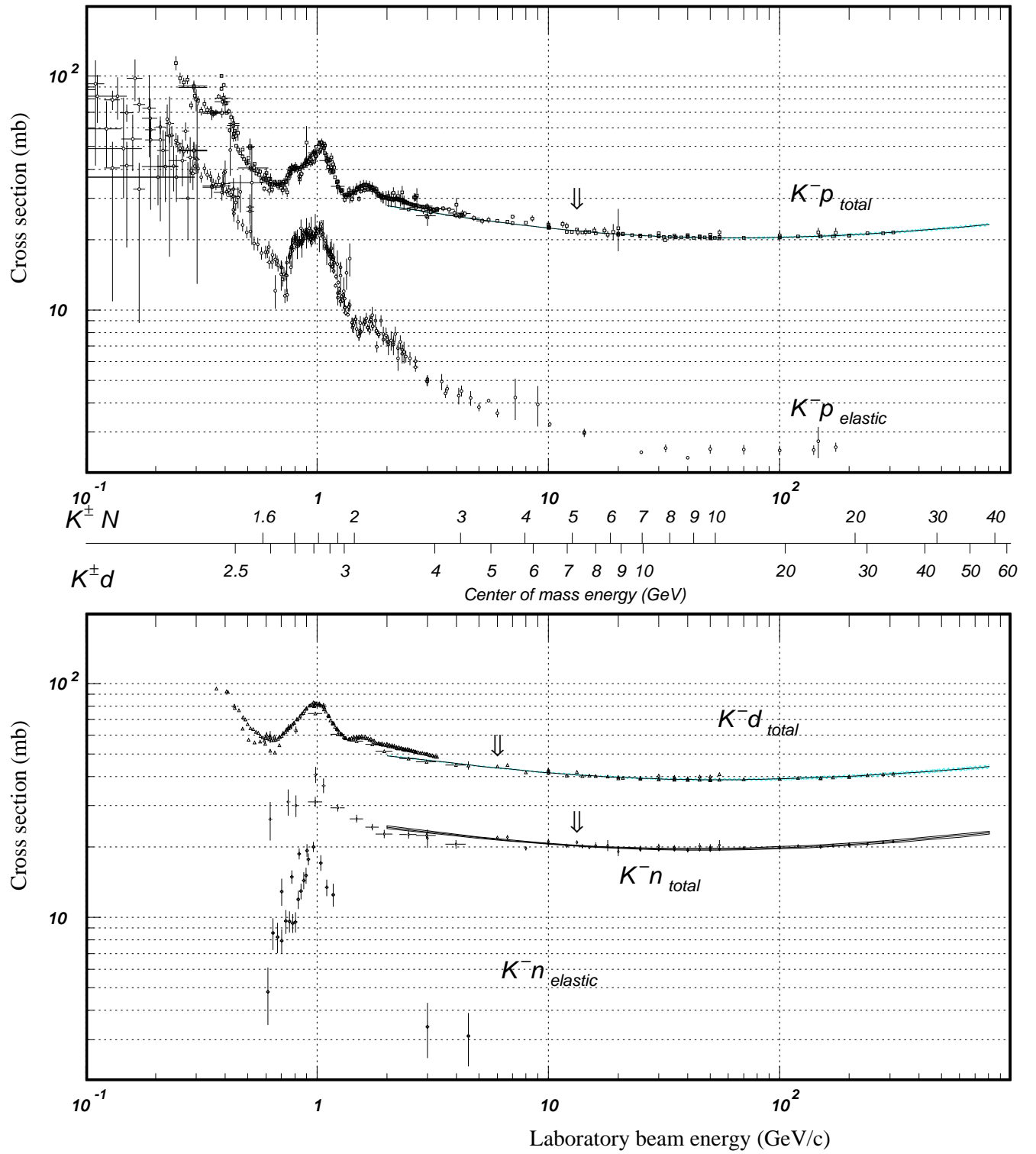


**Figure 37.20:** Total and elastic cross sections for  $pd$  (total only),  $np$ ,  $\bar{p}d$  (total only), and  $\bar{p}n$  collisions as a function of laboratory beam momentum and total center-of-mass energy. Corresponding computer-readable data files may be found at <http://pdg.lbl.gov/xsect/contents.html> (Courtesy of the COMPAS Group, IHEP, Protvino, Russia, August 2001.)

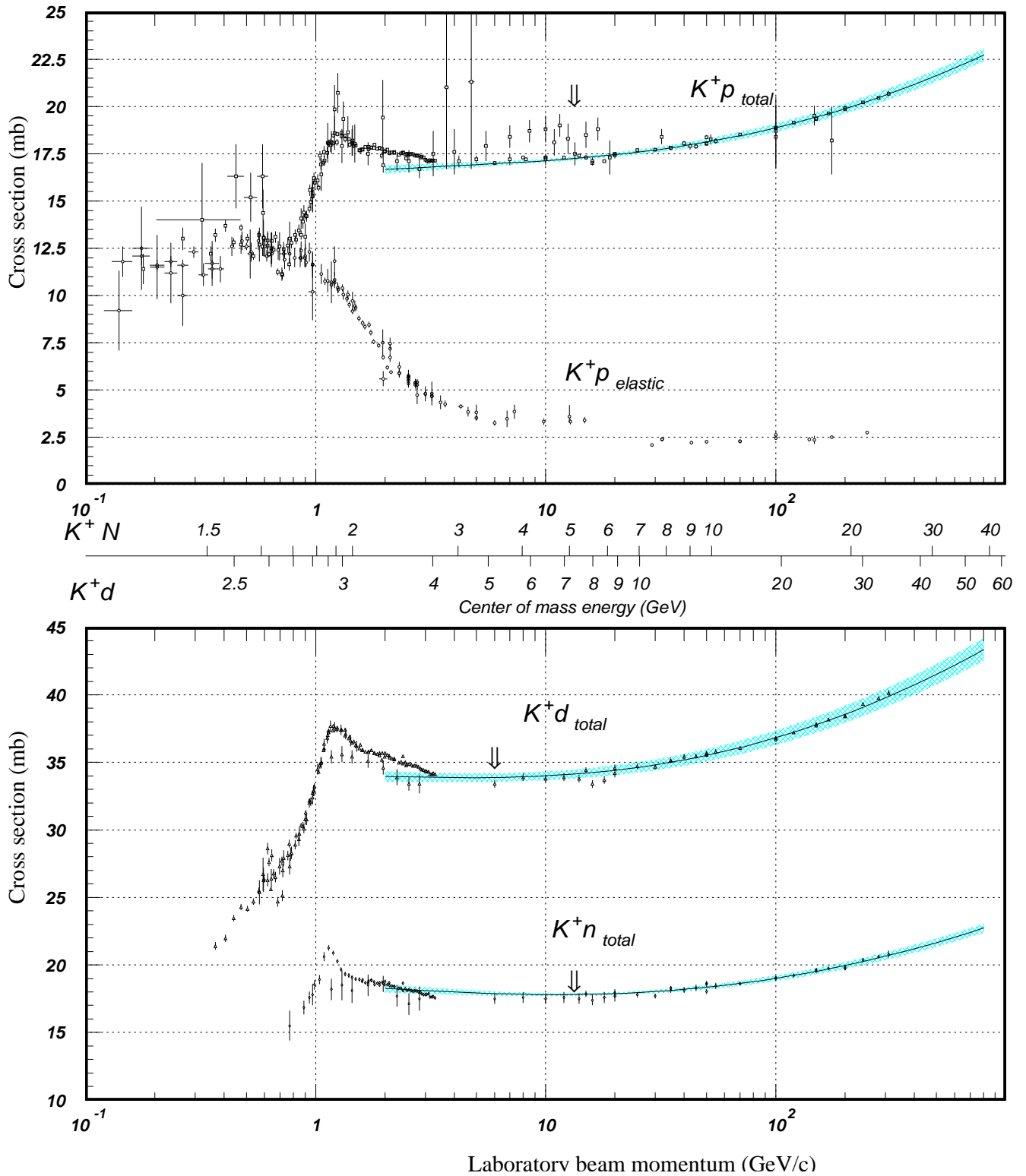


**Figure 37.21:** Total and elastic cross sections for  $\pi^\pm p$  and  $\pi^\pm d$  (total only) collisions as a function of laboratory beam momentum and total center-of-mass energy. Corresponding computer-readable data files may be found at <http://pdg.lbl.gov/xsect/contents.html> (Courtesy of the COMPAS Group, IHEP, Protvino, Russia, August 2001.)

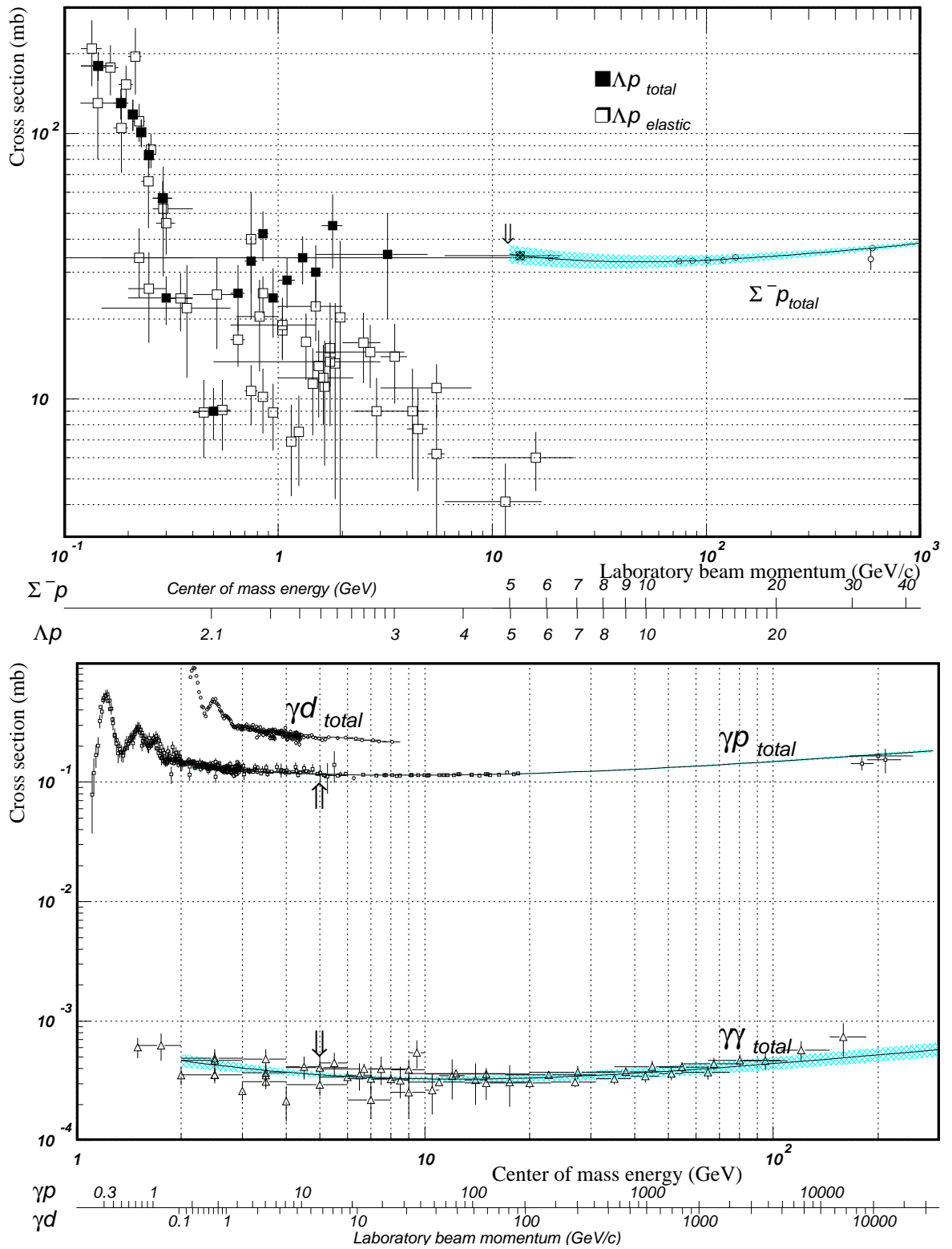




**Figure 37.22:** Total and elastic cross sections for  $K^-p$  and  $K^-d$  (total only), and  $K^-n$  collisions as a function of laboratory beam momentum and total center-of-mass energy. Corresponding computer-readable data files may be found at <http://pdg.lbl.gov/xsect/contents.html> (Courtesy of the COMPAS Group, IHEP, Protvino, Russia, August 2001.)



**Figure 37.23:** Total and elastic cross sections for  $K^+p$  and total cross sections for  $K^+d$  and  $K^+n$  collisions as a function of laboratory beam momentum and total center-of-mass energy. Corresponding computer-readable data files may be found at <http://pdg.lbl.gov/xsect/contents.html> (Courtesy of the COMPAS Group, IHEP, Protvino, Russia, August 2001.)



**Figure 37.24:** Total and elastic cross sections for  $\Lambda p$ , total cross section for  $\Sigma^- p$ , and total hadronic cross sections for  $\gamma d$ ,  $\gamma p$ , and  $\gamma\gamma$  collisions as a function of laboratory beam momentum and the total center-of-mass energy. Corresponding computer-readable data files may be found at <http://pdg.lbl.gov/xsect/contents.html> (Courtesy of the COMPAS group, IHEP, Protvino, Russia, August 2001.)